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PROPOSED PROGRAM FOR WATERSHED MANAGEMENT RESEARCH IN THE LOWER CONIFER ZONE OF CALIFORNIA

H. W. ANDERSON

PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION
BERKELEY, CALIFORNIA

U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

SUMMARY

Thirty-two percent of the State's streamflow comes from the Lower Conifer Zone--the commercial forest below the snow zone. Heavy rainfall augmented by rapid snowmelt combine to make flood potentials high in this zone. The many demands of timber production, flood and sediment protection, wildlife and livestock grazing, and public recreation are higher in this zone than in any other water producing zone in the State.

Research is needed to guide management and predict the consequences of alternate methods of managing these watershed lands. Such predictions must be in terms of the effects on water yield, timing of yields, water quality, floods, and sedimentation.

Watershed management research in the Lower Conifer Zone should take a four-pronged attack: (1) inventory of present conditions of water yield, land conditions, soils, and flood potentials; (2) basic studies of forest hydrology which will suggest methods of land management for improving water yield, preventing floods and controlling sediment, (3) plot and small scale tests of management methods, and finally (4) pilot testing of watershed management alternatives on whole watersheds.

How forests are logged may influence water yield. Some early studies in this zone indicate that water may be saved by cutting small openings in the forest; savings of 10 inches per year were measured in a 5-year plot study in the southern Sierra. The saving persisted in the dry year of 1943-44, thus creating a normal yield from the cut area as contrasted with a half-normal yield from the uncut forest. Other methods need thorough study.

In an Oregon area, similar to California's North Coastal Region, the maximum flood potential has been found to lie in the zone between elevations of 2,000 and 4,000 feet. Methods need to be developed and tested for mitigating floods and sedimentation in this zone.

A ten-year program is proposed for California's Lower Conifer Zone:

1. Establishment of experimental watersheds in four commercial timber areas: Southern Sierra, northern Sierra, interior Douglas-fir, and coastal Redwood-Douglas-fir regions.
2. Establishment of basic and small scale studies at existing experimental forests, and
3. Assembling a team of 10 professionally trained meteorologists, engineers, soil scientists and foresters.

Thirty-one suggested studies are listed.

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PROPOSED PROGRAM FOR WATERSHED MANAGEMENT RESEARCH IN THE LOWER CONIFER ZONE OF CALIFORNIA

By. H. W. Anderson

Californians demand many things of their watersheds--timber and forage, minerals and oil, recreation and hunting, and most of all, water. All of us want more water, we want it pure, and we want it where and when it is needed. Farmers want water in time to irrigate and they want it to be inexpensive; water and power companies want a uniform supply; and flood engineers want water under control. Tomorrow the needs will be greater. To meet them, we must learn how to make every California watershed do its best.

California's Lower Conifer Zone includes the watersheds in that part of the commercial forest belt where a melting winter snowpack contributes less than half of the streamflow in an average year (Colman, 1955). The zone presents special problems in coordinating management for water and for other products, such as timber, minerals, forage, and recreation.

Water is a major product of this 12-1/2 million acre area. Thirty-two percent of the State's streamflow comes from this zone (Colman, 1955, fig. 1). And floods--the zone is frequently subject to combinations of heavy rainfall and rapid melt of shallow snowpacks which result in floods and sedimentation damages.

But other products and problems are important, too. About 80 percent of the State's annual timber harvest is produced in the zone. Wildlife, livestock grazing, and tremendously increasing public recreation use make important local demands. Fire hazards and risks are high, and protection and fire control are major requirements throughout the area. Mining has played a large part in creating bare soil areas, areas of dredging debris, and sediment loads in streams. Except for mining and probably livestock grazing, the many forest demands are likely to increase. In this zone, conflicts of interest are likely to be more intense than in any other water producing zone in the State.

What can research do? The job of watershed management research is to conduct studies which will suggest better methods of management for water and predict the effects of any possible forest or land management practice upon streamflow, water yield, and sedimentation. Since tomorrow's demands upon this zone may be completely different from today's, research must span the possible practices, not just aim at the immediately practical. Besides predicting the consequences of existing and planned practices, research results will suggest ways to manage watersheds that will do the following:

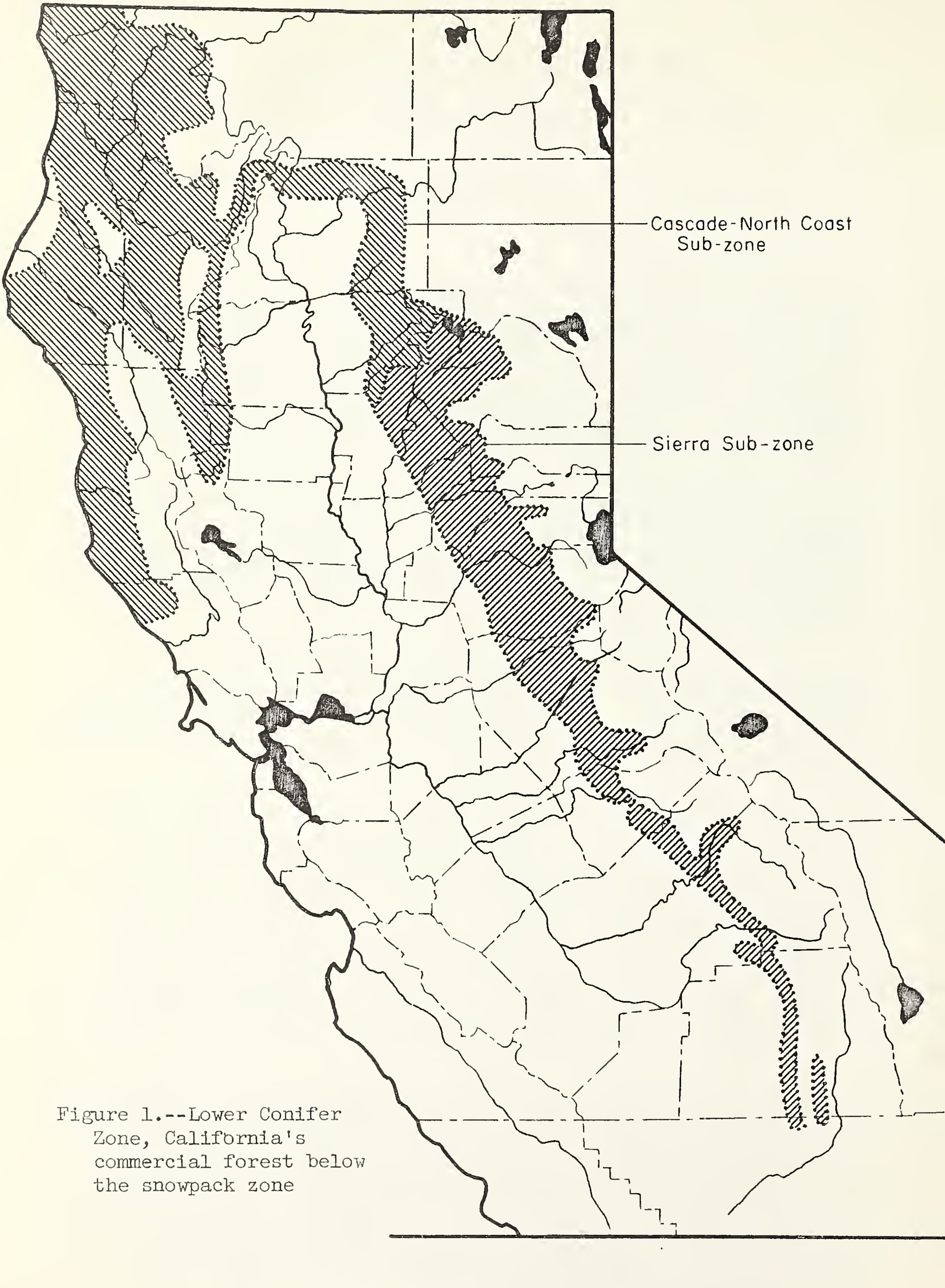

Figure 1.--Lower Conifer Zone, California's commercial forest below the snowpack zone

1. Increase total streamflow in all years, and especially in dry years.

2. Improve the timing of streamflow by reducing winter flood run-off and by reducing water losses in the late spring and summer.

3. Maintain water quality.

4. Minimize local floods and reduce the sedimentation damages.

The Lower Conifer Zone

For watershed research, the Lower Conifer Zone is in reality two distinct problem areas--the Sierra and the Cascade-North Coastal (fig. 1). The Sierra area extends along the west side of the Sierra Nevada, roughly from Kern County northward to Tehama County. Elevations range from 3,500 feet to 5,000 feet in the southern Sierra, and from 1,500 feet to 3,500 feet in the northern Sierra. In the Cascade-North Coastal area, the 3,500-foot elevation marks the upper boundary, whereas the lower boundary ranges from sea level near the coast to about 1,500 feet where the Cascades meet the Sierra Nevada.

The Sierra Problem Area

This area contains two principal timber types: a pine type--mostly ponderosa--at the lower elevations and warmer sites, and a mixed conifer type--pine-Douglas-fir-white fir--on the higher and more moist sites. The pine type and the mixed conifer types each make up about 1,700,000 acres. Another 700,000 acres of forest land are non-stocked. So the Sierra Zone may be said to contain about 4,100,000 acres. About 1/3 of the pine belt and about 2/3 of the conifer belt are still in old growth. Much of the State's timber harvest is from these old-growth stands, and they are the source of about 30 percent of California's annual lumber production. Water production from the Sierra portion of the Lower Conifer Zone is about 7.4 million acre-feet annually.

The Cascade-North Coastal Problem Area

This area includes three principal commercial forest types: the pine-Douglas-fir-fir, the pure Douglas-fir, and the redwood types. The redwood type occupies a narrow coastal belt; inland, a wider belt of Douglas-fir extends to approximately the Coast Range divide; and then the pine-Douglas-fir-fir type spreads down the eastern slopes and across to the east flank of the Sacramento Valley.

The inland mixed conifer and Douglas-fir types occupy about 2,000,000 acres, redwood type 4,200,000 acres. About 800,000 acres are non-stocked. Old growth dominates in these types--79 percent old growth in the inland types and 57 percent in the redwood type. This area produces 50 percent of California's annual timber production--40 percent from the coastal Douglas-fir and redwood types, and 10 percent from the inland type. This part of the Lower Conifer Zone produces about 15 million acre feet of water annually.

A Research Pattern

Since these two areas are such high water producers, it can be said that much of California's timber and water are being produced together. Management decisions are being made now and others will have to be made in the future which will affect how this water is delivered. What kind of research is needed in this commercial timber zone to supply information needed to improve management decisions?

A four-pronged research attack is proposed:

1. Inventory of the present conditions of water yield, land conditions, and soils in the zone.

2. Basic forest hydrology studies which will guide development of methods of improving water yield, preventing floods, and controlling sedimentation.

3. Plot and small scale tests of alternative methods of management for water.

4. Pilot testing of selected methods on experimental watersheds for their effects on streamflow and sedimentation.

INVENTORIES

Zone-wide inventories of water, land condition, and soil are a logical first step. These inventories will identify more clearly the conditions requiring research and point out how much land is subject to various management practices and where each practice will have the most effect.

Water Yield, Flood, and Sedimentation Inventories

To develop methods of improving water yield from a zone, we must first know where the water yield is coming from, in what amounts, and at what times; where floods are produced and with what frequency; and where the principal areas of sediment production are. Each of these questions presents different problems in the Sierra and the Cascade-North Coastal Areas.

Water Yield from the Sierra Area

Problems of water yield in the Sierra area involve the amount of yield, the timing of the yield, and the variability of the yield. There is some evidence that water yield could be increased by cutting of the forest in this zone. Plot studies by the Experiment Station in the years 1940 to 1945 at Bass Lake showed that when a small opening was cut in the forest and all vegetation was removed, interception and evapotranspiration losses were less and water was saved (Rowe and Colman, 1951, pp. 42-46). In the first 3 years, 10 inches were saved in the cut area; in the last 2 years, when roots invaded part of the cut area, only 8 inches of water were saved. These studies were of a 6-foot deep soil with a rather high moisture holding capacity--about 23 to 26 inches. About two-thirds of the saving was a reduction in interception, therefore this part would be saved even on shallower soil areas.

One of the big problems of water yield in the Sierra area is that the yield is somewhat variable. Two to three years in each 10 are dry years--that is, have less than one-half normal streamflow. Can water yield be increased in these dry years by management of the land? Ten inches of water were saved in the dry year of 1943-44 in the Bass Lake study. This much saving would have created a year of normal water yield from the cut-over area as contrasted with the one-half normal yield from the unlogged area.

Cascade-North Coastal Water Yield

Water yield from the Cascade-North Coastal area is characterized by being much greater in amount than that from the Sierra area, and somewhat less variable from year to year. No studies have been made of the effect of watershed management on water yield in this area. To guide such studies, analysis should be made of presently available water-yield information to determine how much water each part of this zone is contributing and when the water is yielded.

Flood Flows from the Sierra Area

The commercial forest zone in the Sierra has never been analyzed as a distinct entity to determine flood potentials of its various units. Some analyses have been made for the entire Sierra slope from the foothills up through the alpine zone. The results say chiefly that floods are less from those high elevation watersheds because most of the precipitation occurs as snow. Analyses were made of the relation of flood flows from 1 to 120 days to topographic conditions by Kuhnel (1949). Some of his observations are pertinent:

"(1) As the latitude increases, there appears to be a general increase in long duration depth of flood runoff and a general decrease in short duration depth of flood runoff. (2) The higher in elevation and closer a windward barrier mountain ridge is to a stream basin, the less the depth of runoff from that stream basin. (3) Large basins (having an area of more than 100 sq. mi.) located on the back or lee side of a mountain range experience considerably less depth of flood runoff than large stream basins located on the front or windward side of a range, but small stream basins located within five or ten miles of the mountain crest experience about the same depth of runoff on either side. (4) Winter rain runoff depths in general reach their greatest values on stream basins located at a mean elevation somewhere between 3,000 and 4,000 feet, while summer snowmelt runoff depths reach their greatest values somewhere between 7,000 and 9,000 feet..... (7) The presence of large lakes and swamps in a stream basin tends to reduce the depth of flood runoff. (8) Great depth of soil and great density of vegetative cover on a stream basin tends to reduce the depth of flood runoff."

More recently Todd and Ateshian (1956) made a similar analysis relating peak flows to topographic variables. Their analyses indicated that the area of the watershed, the precipitation intensity, and the range in elevation were the chief parameters relating flood flows to topography and precipitation.

These two reports serve as first steps in the analysis of the origin of flood waters; more detailed analyses need to be made, specifically relating flood peak discharges to terrain variables and land conditions.

Flood Flows in Cascade-North Coastal Area

No analyses have been made of the relationship of floods to topographic variables or land use variables in this zone. However, some analyses made of floods in western Oregon are indicative of this zone. Analyses by Anderson and Hobba (1959) indicated the frequency of rain and snowmelt contribution to floods and the relationship of slope exposure, geology, and forest conditions to flood peak discharges. They found that the elevation zone between 2,000 and 4,000 feet was the principal flood producer. In this zone, rain occurred frequently and snowmelt contribution to flood flows was also high, as shown in the tabulation on the next page. Their analyses indicated that the north facing watersheds were the highest flood producers, probably because of greater soil moisture on these watersheds and possibly because snow lying at lower elevations was melted by rains and contributed to the floods. Geologic types contributed differently to floods in this order: old volcanics first, young volcanics next, marine sediments third, and recent alluvium last. Forest conditions also contributed to floods. They found that if one square mile of forest were cut off, flood peak discharges from that watershed would be about 100 second-feet greater. This increase in flood peaks diminished as the forest was restocked and became older.

Elevation, feet:	Relative rain area frequency	Relative snowmelt frequency	Relative precipitation	Relative flood potential
0-1,000	1.00	1.00	1.0	1.0
1-2,000	.96	.99	1.5	1.5
2-3,000	.87	.92	2.1	1.9
3-4,000	.74	.82	2.4	1.9
4-5,000	.60	.74	2.4	1.7
5-6,000	.39	.48	2.4	1.0
6-7,000	.17	.38	3.1	0.6

Similar analyses to these might be made in the Cascade-North Coastal and Sierra Areas of California's Lower Conifer Zone. They would point the way to localities of high flood potential and guide research on flood prevention.

Sedimentation in the Sierra Area

For the Sierra Nevada as a whole, sediment production is rather low (Brown 1947). Local problem soils, however, may yield considerable sediment when the natural cover is disturbed by fire, logging, road building, or other disturbances. Analyses are needed which will identify and locate these problem soils and show the relationship of land use to sedimentation.

Sedimentation problems of the Cascade-North Coastal Area

No analysis has been made relating sediment production to topographic and land use conditions in the Cascade-North Coastal Area. However, in recent years, suspended sediment has been measured in a number of watersheds. These measurements indicate sediment production may be higher in this zone than was previously thought.

Analyses in geologic types similar to those in the Cascade and Coastal Zones in western Oregon may further indicate some of the problems.

Anderson (1954) found that sediment production in western Oregon was greatest from those areas where total runoff was greatest, where the ratio of rainstorms to snowstorms was highest, and where there had been recent cutover and road construction. Some 54 percent of the total sediment production was associated with channel cutting in the main valleys below the forest areas. Soils developed on the various geologic types showed wide variation in susceptibility to erosion, that is, in suspended sediment production (table 1). Where rainfall intensity, slope, and other factors contributing to erosion were equal, the soils developed on recent and young volcanics were the most erodible. Granitic rock types and marine sediments were next, and recent alluvium was least erodible. Similar analyses might be a first step in the study of sedimentation problems in the Cascade-North Coastal and Sierra Areas.

Table 1.--Physical characteristics of surface soil and relative erosibility of major soil-geologic types of western Oregon 1/

Geologic types	Geological symbol 1/	Particle size distribution diameters-mm 0.05	0.05-2	2-5	5	Suspension 2/	Aggregated si + cl 3/	S/A 4/	Se 5/	Relative erosibility 6/
		pct	pct	pct	pct	pct	pct	cm²/gm pct	pct/100	
Alluvium	Qa	25.1	10.6	27.6	36.7	5.7	19.4	0.37	143	0.7
Recent volcanic	Qv	16.9	73.5	5.3	4.3	10.2	6.7	2.75	2450	7.7
Young volcanic	QPv	19.6	54.9	12.0	13.5	11.0	8.6	2.04	2290	4.7
Columbia basalt	PMv	20.1	20.2	26.2	33.5	6.8	13.3	0.59	420	1.0
Miocene marine	Mm	32.0	10.4	31.9	25.7	8.6	23.4	0.26	227	2.6
Oligocene marine	[illegible]	24.9	16.4	34.6	24.1	7.1	17.8	0.41	329	1.8
Eocene marine	Em	24.2	19.1	28.2	28.5	7.2	17.0	0.62	427	1.6
Eocene volcanic	Ev	40.5	12.6	26.8	20.1	10.0	30.5	0.17	182	6.2
Cretaceous marine	K	31.0	27.0	23.8	18.2	15.4	15.6	0.57	858	3.3
Jurassic Triassic	JTR	19.4	14.1	28.7	37.8	6.1	13.3	0.53	331	0.9
Old intrusive	Ji	20.2	50.6	22.8	6.4	10.8	9.4	1.64	1660	2.8
Carboniferous volcanic	Cv	30.9	34.9	20.9	13.3	13.6	17.3	0.68	891	3.7
Carboniferous	C	31.1	22.4	23.6	22.9	17.8	13.3	0.60	1070	1.8
Devonian	D	25.2	6.7	22.2	45.9	5.9	19.3	0.23	189	1.2
Agricultural 7/	..	19.5	3.8	57.4	19.3	4.6	14.9	0.35	101	...

1/ Source: Anderson 1954, p. 27.
2/ Geologic Map of United States, U. S. Geological Survey, 1932.
3/ MIDDLETON (1930); all percentages given are per cent of whole soil.
4/ Ultimate silt plus clay (particles 0.05 mm in diameter) minus suspension.
5/ Defined in text.
6/ From (5) using particle size 0.05 mm for SC and values of S/A from this table; relative values assigned by taking PMv geology as 1.0.
7/ Based on two samples.

Inventory of Forest Conditions in the Lower Conifer Zone

A more detailed inventory of the forest and other land conditions is needed to show the location, extent, and kinds of forests and their densities, the sizes of openings and ground conditions--brush, grass-herb, and bare ground, the areas of riparian stream-bottom growth, and the topographic conditions where each condition occurs. Some general summaries of the timber types in the commercial timber zone below the snow may be obtained from Forest Survey data (U. S. Forest Service, 1954).

These data, however, are for broad, highly generalized forest types (table 2). More specific information is needed to plan research which will guide management of the various forest sites and stands found within these general types. How much brush is co-mingled with timber stands? What is the area of water-loving plants along stream channels? What is the extent of mountain wet meadow lands? Answers to these questions will guide research aimed at developing methods which will improve or maintain water yield.

Table 2.--Commercial forest land area, by forest type and subregion, Lower Conifer Zone 1/

Forest type	Sierra Westside subregion	Coast Range Pine subregion	Redwood-Douglas-fir subregion	Total
	Thousand acres			
Pine	1,715	213	10	1,938
Redwood	--	--	1,918	1,918
Douglas-fir	--	476	2,005	2,481
Pine-Douglas-fir-Fir	2/ 1,695	2/ 1,212	266	3,173
Non-stocked	692	326	548	1,566
Total	4,102	2,227	4,747	3/ 11,076

1/ Source: U. S. Forest Service, 1954.
2/ The other half of this type is in the snow zone.
3/ Reserved land such as parks are not included in these figures.

Soil Inventories

Soil-vegetation maps are being made for some of the areas in the commercial timber zone. Maps are available for Humboldt, Lake, Glenn, Tehama, and Mendocino counties. Soon maps of Shasta and Fresno counties will be available. These and subsequent soil-vegetation surveys will help guide research; however, we need special inventories of the hydrologic characteristics associated with the soil-vegetation types and geology of the areas.

We need to know answers to such questions as--What is the extent of soils with various water holding capacities? What are the physical characteristics of the soils developed on various geologic types and their erodibility? What is the usual water use by transpiration and evaporation from soils on various aspects and slopes and for soils of various depths?

Plans for Inventory Studies

Several studies involving inventories of the water, forest conditions, and soils are currently under way for the snow zone of California, under a cooperative snow management research program between the Pacific Southwest Forest and Range Experiment Station and the State Department of Water Resources. Extension of these studies (under a separately administered and financed research program) to the Lower Conifer Zone would be relatively easy and would facilitate the studies for both the snow zone and the zone below.

Water-holding capacities of the soil, summer water losses, and erodibility may be sampled by determining their variability in different geologic formations and slope exposures and vegetation conditions. Modern equipment, such as the radioactive soil moisture probe, will speed these determinations in mountain soils. Such a study would be one of the greatest single strokes that could be made for watershed management research in California.

Sampling of soil-moisture characteristics and losses over say, a 3-year period, relating them to the physical characteristics of the site and the forest where they occur, and testing these relationships in new areas would constitute the first steps of such a program. From these relationships would come sure knowledge of the range in water losses associated with various physical conditions, of prospects for reducing water losses, and an idea of the areal extent of various conditions subject to any methods of water improvement that were developed.

These inventory projects would involve the full time of a hydrologist, a soils specialist, and a forester for about 3 years. Annual cost of the projects would be approximately $40,000 per year.

STUDIES OF BASIC HYDROLOGIC AND SEDIMENTATION PROCESSES

Hydrologic Processes

Hydrologic processes are those actions of the vegetation, the topography, and the climate, which influence the movement of precipitation after it has fallen--in other words, what happens to rainfall. Study of these processes will give answers to many questions: How much rainfall is intercepted by vegetation and evaporated, in different cover types, storm sizes, and precipitation intensities? The studies will answer water loss questions: How much of the water is lost by evapotranspiration on side slopes of mountain areas, in riparian areas, from tree, brush, or grass cover, under different terrain and soil conditions? How much water is gained by fog dripping from trees along the coast? The studies will answer water yield questions: How is water yielded at different forest sites--how much runs over the surface? How much percolates shallowly into the soil and comes out as quick seepage? How much goes into ground water storage and ground water yield? The studies will answer flood control questions: How frequently and by what processes does rain and snowmelt in this zone contribute to floods, and how do various forest conditions affect such contributions? What are the effects of forest fires, logging, grazing, and type conversion on these hydrologic processes?

Behind any of these hydrologic process studies must be an understanding of the basic micrometeorological conditions of forest sites. This knowledge will speed the development of the most effective methods of producing water yield on the myriad topographic, forest, and other land conditions one finds in so-called forest belts of the State. How much radiation is received on the various slopes and under different forest conditions? What happens to this energy--how is it disposed of by reflection, by long-wave radiation, by convective and conductive heat losses? How does wind influence advective snowmelt, evapotranspiration, and interception losses? Can we "short cut" and speed up this mass of measurements by using some rather simply measured indexes of micrometeorological conditions?

Sedimentation Processes

Sedimentation process studies will help predict erosion production from the different forest and other land conditions. How much ground cover is needed to give specified levels of protection to the soil under prevailing rainfall intensities and soil erodibilities? What are the relations of steepness of slope and length of overland flow to the ground cover needed to prevent gullying? What are the effects of wildfires and land treatments? If roads are the bad actors that some think, what road design, drainage, and maintenance conditions are needed to establish a given level of erosion control on different soil types?

These studies of basic hydrologic processes and sedimentation processes promise to shorten the time when answers can be given which will apply to the many thousands of forests and site conditions that one encounters in the Lower Conifer zone.

Plan for Basic Hydrologic and Sedimentation Studies

Basic studies will be carried on at field installations and in laboratories. Field studies will be established in conjunction with one of the experimental forests in the Sierra Zone and another in the Cascade-North Coastal Zone. This might well be done by the use and extension of facilities now available at the Redwood Experimental Forest near Eureka, The Jackson State Forest near Ft. Bragg, the Challenge Experimental Forest near Oroville, and the Big Creek Demonstration Area near Fresno (fig. 2). Laboratory studies needed to answer those questions that can be best answered with models, can be conducted in Forest Service laboratories at Berkeley, the Institute of Forest Genetics at Placerville, and the San Dimas Experimental Forest, or in laboratories of cooperators such as the University of California. The basic hydrologic and sedimentation studies will require the services of a meteorologist, a forest hydrologist and a soils specialist, with annual cost averaging about $60,000 per year.

PLOT AND SMALL SCALE TESTS

Plot and small scale tests are the first practical evaluations of the effects of any management method on water yield and they will give the first indices to flood and sedimentation consequence. Many special problems are amenable to tests on plots--effects of fire, effects of brush conversion, effects of various logging methods and slash disposal methods, and effects of forest grazing. By measuring the effects of various types of management on soil moisture losses, interception, and evapotranspiration, we may be able to approximate rather closely the resultant effects on streamflow. Plot tests, too, should be the first step in testing various hypotheses of "ideal forests" for water conservation or flood and sediment control. From these plot tests can come the best methods for testing on pilot plant watersheds.

Plan for Plot Studies

Plots will be established as needed, usually in conjunction with or near experimental forests, or in active forest operations. The plot studies will be under the direction of a research forester or other professional men. Costs are estimated at $30,000 per year for the duration of the project.

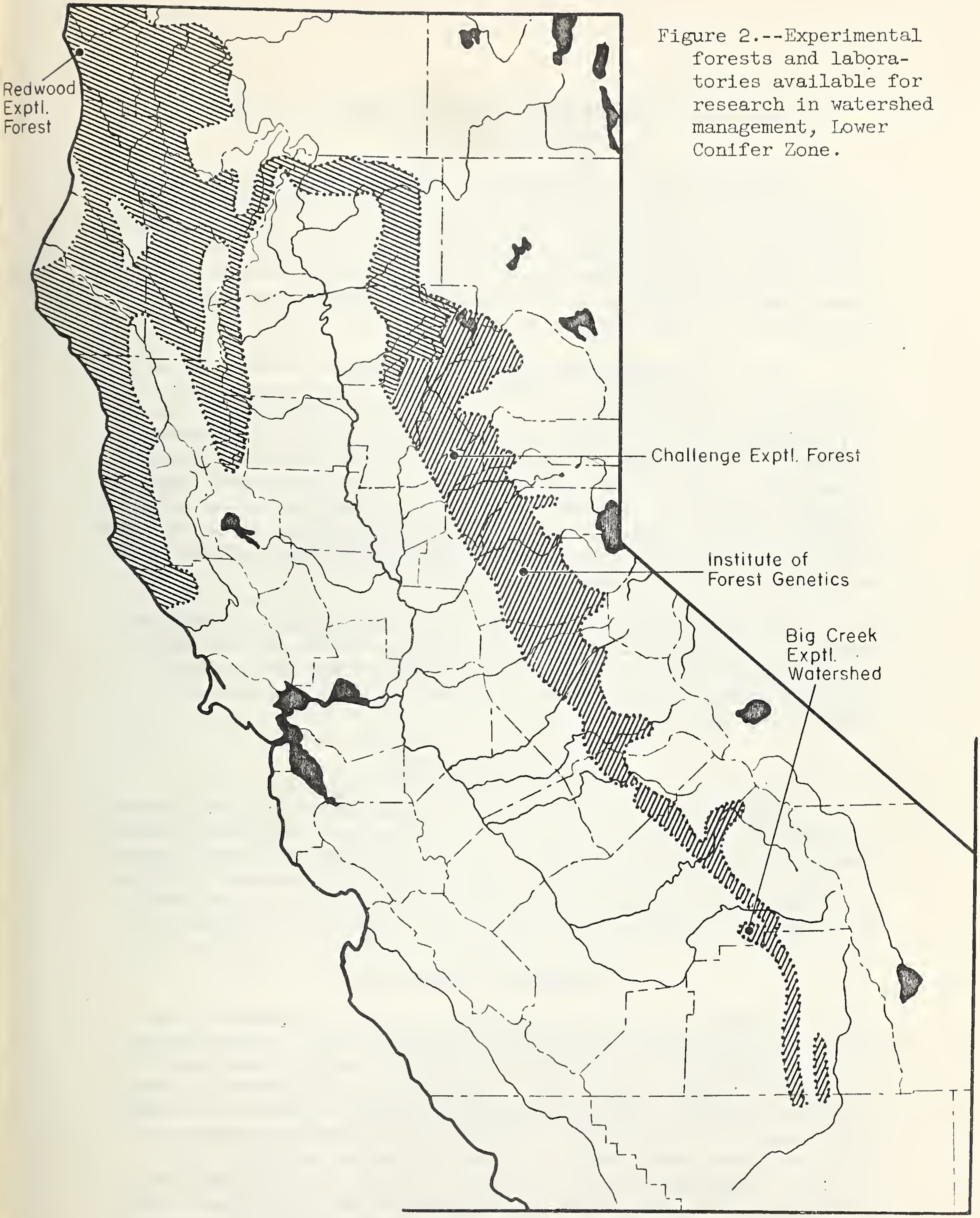

Figure 2.--Experimental forests and laboratories available for research in watershed management, Lower Conifer Zone.

CALIBRATION OF WATERSHEDS FOR PILOT TESTING OF WATERSHED MANAGEMENT METHODS

No matter how encouraging the results of plot studies, they must be further evaluated by pilot tests. These tests, to be as conclusive as possible, must be made on whole watersheds and the end products must be measured in terms of streamflow and sedimentation. The possibility that these effects may have been due to chance must be evaluated--statistical significance should be established, if possible.

Pilot tests on whole watersheds take time. First, we must make sure of the behavior of each watershed over several years so that we may predict its behavior quantitatively--streamflow and sedimentation--in the years that will follow. Then we must apply our tests to one of the watersheds or several tests to several watersheds. Since these tests involve both how the forest reacts to what we have done and how it reacts under the particular climatic conditions that happen to occur, we must be prepared to measure the effects of the forest treatment for several years before the final evaluation of the treatment can be made.

Experimental watersheds for pilot testing must be equipped with accurate streamflow and sedimentation measurement devices. Meteorological measurements must be made at a nearby standard meteorological station or in a newly established station, if none is nearby.

Streamflow Measurements

Streamgaging stations in pilot watersheds should be located at places where no groundwater flow will by-pass the gaging station. Weirs to measure the streamflow with an absolute accuracy of about 2 percent or better, and an accuracy of 1/2 of 1 percent relative to companion pilot watersheds should be aimed for. Weirs should be designed to measure the 50-year flood without over-topping.

Sedimentation Measurements

Sedimentation should be measured by debris basins placed ahead of the streamflow measurement device. These basins should be designed to have equal trap efficiency, that is, have equal watershed area-capacity ratios. In this way, each of the pilot watersheds, though differing somewhat in actual size, will catch fair samples of the sediment production from the watersheds. It has been found advantageous to place a V-notch weir in a crest of small, dam-like structures, hence creating the stilling pond for the weir and the sediment trap basin at the same time. Suspended sediment outflow from these small basins can be measured with portable samplers.

Meteorological Measurements

It is essential in characterizing the calibration and treatment periods of a study that meteorological measurements be made which are independent of any treatment. If a standard Weather Bureau station exists nearby, rather short-term records at the experimental pilot watersheds may suffice to show that the standard meteorological measurements at the Weather Bureau station may be used as a control. Wind velocity and direction should be measured in some highly exposed site, or above the top of the trees.

The Plan for Pilot Watersheds

Three to five watersheds in each of four areas should be selected. Streamgaging stations and sediment basins are to be established and meteorological records taken as soon as research in the Lower Conifer Zone starts. One of the sets of watersheds should be in the southern Sierra, another in the northern Sierra, one in the pine--Douglas-fir--fir type in the Cascades, and the last in the coastal Douglas-fir timber type. In each set of watersheds one or more watershed should sample some hydrologic characteristic of special importance in the region--slide areas in north coastal area, lava flow in the Cascades, and erodible granitic rock of the southern Sierra. Plans should be made for measuring streamflow continuously for a period of five years or more before any treatment, that is, until the watersheds are calibrated, and then for another period of five years or more after any treatment, or until the treatment effect has been fully evaluated.

Both sediment deposition and suspended sediment should be evaluated. Sediment deposition in the debris basins should be measured at least annually in each of the watersheds. Suspended sediment outflow from the basins should be measured so as to have outflow estimates for every level of discharge; from these and the discharge records total sediment outflow can be computed. Meteorological measurements should be taken near the experimental watershed until such time as a satisfactory correlation can be made with other long-term weather records.

The experimental watersheds should be inventoried to show the forest types and conditions, timber volumes, ground vegetation, and geology and soils and their water holding characteristics. Such experimental watersheds should be formally established as Experimental Forests or Laboratories and have no changes in the land use during the calibration period.

Experimental watersheds should be put in charge of an experienced project leader who will oversee establishment of the watersheds prior to treatment, supervise the collection and processing of the data from the watersheds, and participate in the analyses of the data. Costs of the project will be about $90,000 for the first two years and taper to $30,000 thereafter.

Cooperation of the U. S. Geological Survey in supervising the taking of streamflow data and in publishing the records should be sought. The cooperation of the Weather Bureau should be sought in the taking of the standard weather measurements, or at least liaison with them established and maintained.

After the watersheds are calibrated they will be used to test the consequences of various management practices in terms of changes in streamflow and sedimentation. The practices applied will include those expected to bring about maximum differences in water yield and those in which water yield is compromised for flood prevention, production of timber or forage, or recreation. Appropriate experts in timber, recreation, and range management together with economists will be asked to evaluate the benefits and costs of these in each treated watershed. Watershed management experts will participate in evaluation of the water costs and benefits.

OPERATING PROCEDURES

Studies

Studies should be designed and executed under the general guidance of this project analysis plan and its amendments. A specific study plan will be made before the start of any study. The study plan shall be in writing, shall be reviewed by two or more of the project technical staff, revised as needed, and then submitted for approval to the Research Leader and the Division Chief. Study plans will be submitted to any cooperators in the study. When the study is installed, an establishment report will be written, covering the exact location of the study, measurements taken, the accuracy to which they will be read, and any deviation of the plan as installed from the plan originally submitted and approved. Supplements will be written to cover any change in the original plan, additions to the original plan, or details of procedure. Formal approval of these is also required. Each study plan will contain these elements:

1. An introduction which outlines the problem, points up the need for the research, and what part the study plays in the general research plan.

2. The objectives of the study: Why do this? Why do it now? Specifically, what does the study aim to answer?

3. Past work and pertinent results. Who has worked on this problem? What were his results? What did he suggest when you wrote to him?

4. Scope of the study. Is the study a reconnaissance or a definitive study? How is this study limited in time, space, comprehensiveness?

5. Methods of the study. What the research worker is going to do, where and how. This section should include sample forms and data processing methods. If specific methods cannot be spelled out now, state how the specific method will be decided.

6. Equipment and personnel time required for the study.

7. Programming of the study. When should what be done and by whom. How are data to be collected and analyzed?

8. Personnel assignments. Project leader, assistants, what part of time each will be required to work on this study and for how long.

Reports

Annual progress reports will be completed and submitted to the research leader for summarization with other study reports. Summary progress reports will be submitted to cooperators and for division and Station Director's review. A 5-year summary report and a new project analysis will be prepared at the end of the first 5 years of the project.

LIST OF POSSIBLE STUDIES, WATERSHED MANAGEMENT RESEARCH LOWER CONIFER ZONE

Inventory Studies

1. Inventory of water yield from (a) the Sierra Area, and (b) the Cascade-North Coastal Area.

2. Inventory of the forest and land conditions in (a) the Sierra Area, and (b) the Cascade-North Coastal Area.

3. Inventory of soil erodibility in (a) the Sierra Area, and (b) the Cascade-North Coastal Area.

4. Inventory of soil moisture storage and soil moisture losses in (a) the Sierra, and (b) the Cascade-North Coastal Areas.

5. Literature search, critical review, and analysis of effects of forest conditions on water yield, floods, and sedimentation.

Pilot Watershed Establishment

6. Selection and testing of pilot watersheds in (a) the

southern Sierra, (b) the northern Sierra, (c) the Cascade Area, and (d) the North Coastal Area.

Basic Forest Hydrology and Meteorology Studies

7. Heat balance in different forest and terrain conditions as related to (a) water losses, and (b) flood potential.

8. Summer evapotranspiration in relation to terrain and forest conditions in (a) Sierra Area and (b) Cascade-North Coastal Area.

9. Winter evapotranspiration in relation to terrain and forest conditions in (a) Sierra Area and (b) Cascade-North Coastal Area.

10. Fog drip as a precipitation source in various meteorological, topographic, and forest conditions.

11. Horizontal and vertical wind gradients in forests and in openings.

12. Interception losses for various forest conditions and sites, (a) Sierra Area, (b) Cascade Area, and (c) North Coastal Area.

Plot and Small-scale Tests

13. Effects of conversion of brush fields to grass or to trees on soil moisture and interception losses, (a) Sierra Area, (b) Cascade Area, and (c) North Coastal Area.

14. Effect of forest fires on the hydrology of (a) the Sierra Area, (b) the Cascade Area, and (c) the North Coastal Area.

15. The effect of slash disposal methods on soil moisture and other water losses.

16. Micrometeorology on forest sites, logged and unlogged.

Pilot Watershed Tests

17. Improvement in calibration of experimental watersheds.

18. Pilot testing of hypotheses of water control on experimental watersheds in (a) South Sierra Area, (b) North Sierra Area, (c) Cascade Area, and (d) North Coastal Area.

PERSONNEL AND BUDGET REQUIREMENTS FOR THE PROJECT

The project as outlined would require the services of one research leader, three major project leaders, four technically trained assistants to the project leaders, one instrument specialist and about eight sub-professional forestry or engineering aids. A stenographer, a statistical clerk, and two or three student aids would round out the staff. Technical services, including editorial services, statistical services, and data processing services would be obtained from the central station pool in Berkeley. An organization chart is outlined in figure 3. Streamflow checking and publishing of streamflow data would be in cooperation with the U. S. Geological Survey. Budget estimates are summarized in Table 3 for the first five years of the project. Costs of the project for the first five years are approximately $200,000 per year. Estimated total life of the project is 10 years.

Table 3.--Budget estimates. Watershed management research in commercial forest zone (below the snow)

Item	1961	1962	1963	1964	1965
Building construction or remodeling	$ 20,000	$ -	$ 20,000	$ -	$ -
Equipment and instruments 1/	90,000	90,000	47,000	45,000	19,000
Expendible materials and supplies	3,000	3,000	3,000	3,000	3,000
Contracted services	2,000	4,000	8,000	12,000	15,000
Operating expenses	7,000	8,000	9,000	10,000	10,000
Administrative and technical services	33,000	33,000	33,000	33,000	33,000
Salaries	45,000	62,000	80,000	97,000	120,000
Total	$200,000	$200,000	$200,000	$200,000	$200,000

1/ Includes streamgaging and sediment catchment structures.

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
WATERSHED MANAGEMENT RESEARCH IN COMMERCIAL FOREST ZONE
(Below the Snow Zone)

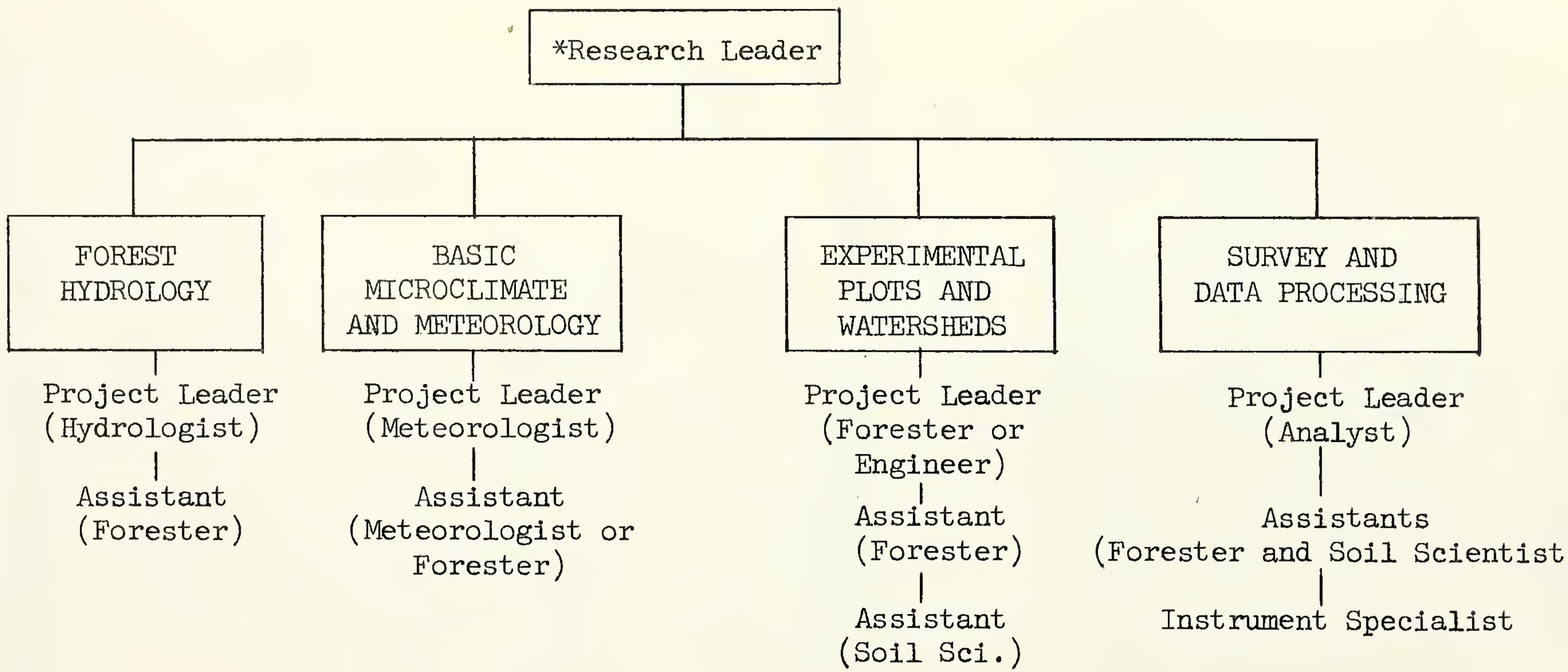

Figure 3.--Organization Chart

*Research Leader will also be Project Leader for one of the four major projects.

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